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A GEOLOGIC RECONNAISSANCE OF THE ISLAND OF MINDANAO AND THE SULU ARCHIPELAGO

I. NARRATIVE OF THE EXPEDITION

By WARREN D. SMITH
(From the Division of Mines, Bureau of Science)

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PREVIOUS PUBLICATIONS OF THE BUREAU OF GOVERNMENT LABORATORIES.

[1] *No. 1, 1902, Biological Laboratory.*—Preliminary Report of the Appearance in the Philippine Islands of a Disease Clinically Resembling Glanders. By R. P. Strong, M. D.

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[1] *No. 6, 1903.*—New and Noteworthy Plants, I. The American Element in the Philippine Flora. By Elmer D. Merrill, Botanist. (Issued January 20, 1904.)

[1] *No. 7, 1903, Chemical Laboratory.*—The Gutta Percha and Rubber of the Philippine Islands. By Penoyer L. Sherman, jr., Ph. D.

[1] *No. 8, 1903.*—A Dictionary of the Plant Names of the Philippine Islands. By Elmer D. Merrill, Botanist.

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[1] *No. 10, 1903, Biological Laboratory.*—Two Cases of a Peculiar Form of Hand Infection (Due to an Organism Resembling the Koch-Weeks Bacillus). By John R. McDill, M. D., and Wm. B. Wherry, M. D.

[1] *No. 11, 1903, Biological Laboratory.*—Entomological Division, Bulletin No. 1: Preliminary Bulletin on Insects of the Cacao. (Prepared Especially for the Benefit of Farmers.) By Charles S. Banks, Entomologist.

[1] *No. 12, 1903, Biological Laboratory.*—Report on Some Pulmonary Lesions Produced by the Bacillus of Hæmorrhagic Septicæmia of Carabaos. By Paul G. Woolley, M. D.

No. 13, 1904, Biological Laboratory.—A Fatal Infection by a Hitherto Undescribed Chromogenic Bacterium: Bacillus Aureus Fœtidus. By Maximilian Herzog, M. D.

[1] *No. 14, 1904.*—*Serum Laboratory:* Texas Fever in the Philippine Islands and the Far East. By J. W. Jobling, M. D., and Paul G. Woolley, M. D. *Biological Laboratory:* Entomological Division, Bulletin No. 2: The Australian Tick (Boophilus Australis Fuller) in the Philippine Islands. By Charles S. Banks, Entomologist.

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[1] Out of print.

[2] The first four bulletins in the ornithological series were published by the Ethnological Survey under the title "Bulletins of the Philippine Museum." Later ornithological publications of the Government appeared as publications of the Bureau of Government Laboratories.

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A GEOLOGIC RECONNAISSANCE OF THE ISLAND OF MINDANAO AND THE SULU ARCHIPELAGO.

I.—NARRATIVE OF THE EXPEDITION.

By Warren D. Smith.
(From the Division of Mines, Bureau of Science.)

CONTENTS.

I. Introduction.
II. Previous investigations.
III. General geographical description.
IV. People.
V. Climate.
VI. The narrative of the expedition.

I. INTRODUCTION.

The Mining Bureau of the Philippine Islands, and subsequently the division of mines of the Bureau of Science, has now been in existence approximately ten years and during this time its scientific employees have visited nearly every part of Luzon and the Visayas, but up to the present the large southern island of Mindanao has been neglected. The reason for this is twofold; work was necessary in other and more important fields and only recently have conditions been such that travel in the greater part of Mindanao has been possible without a regiment of soldiers, although even now it is necessary in many places to take a detachment of from three to twenty men, as the Moros are still disturbing the peace in certain quarters.

One or two localities on the coast were visited by members of the *Cuerpo de Ingenieros de Minas* during the Spanish régime and I shall allude more fully to their work in the following pages.

The existing dearth of information in regard to this island led me, as chief of the division of mines of the Bureau of Science, to undertake a general reconnaissance of Mindanao and the Sulu group. Such a general view is necessary for planning future systematic and more detailed study.

The following four objects were in mind in beginning this expedition: (1) The rapid reconnaissance of the geology; (2) the examination of certain special areas likely to prove of economic interest; (3) topographic route sketching, and (4) securing a knowledge of the work of the prospectors in the field.

The party consisted of Warren D. Smith, geologist in charge; Maurice Goodman, mining engineer; Harry M. Ickis, topographer; Robert N. Clark, assistant; as well as Lieutenant Charles S. Caffery, United States Army, in charge of the military escort. The journey was only made possible by the assistance of the latter and our thanks are due to General Tasker H. Bliss, governor of the Moro Province, and to Lieutenant Caffery for their cordial assistance.

The map at the beginning of this paper shows the position of Mindanao and the Sulu group with relation to the remainder of the Archipelago. Roughly, these islands lie between the parallels 5° and 10° north latitude and between 119° and 127° east longitude. The route of the party is indicated by the heavy line.

The work was divided as follows: That on the Zamboanga Peninsula and the Sulu group was done by W. D. Smith accompanied by Lieutenant Charles S. Caffery; the vicinity of Cagayan and Iligan, Misamis Province, was investigated by H. M. Ickis, assisted by R. N. Clark; W. D. Smith and H. M. Ickis, accompanied by Lieutenant Caffery and an escort, surveyed from Camp Overton through the Lanao Lake country to Cotabato and from Cotabato to Davao; the ascent of Mount Apo was made by W. D. Smth, Maurice Goodman, and H. M. Ickis; Maurice Goodman and H. M. Ickis went from Davao up the Tagum and Sahug Rivers to the headwaters of the Agusan and thence to Talacogon. Maurice Goodman then proceeded to Surigao and Placer, while H. M. Ickis made a reconnaissance to San José de Bislig and back to Talacogon.

II. PREVIOUS WORK OF A GEOGRAPHICAL OR GEOLOGIC NATURE IN MINDANAO.

No attempt will be made to review the work of all the men who have undertaken expeditions through the southern islands of the Philippine Archipelago. I shall confine my attention to those who have contributed in a marked degree to our knowledge of their geology and geography.

The first map of Mindanao which is at all accurate was made by the Jesuit Fathers. Of course, this map is based on little or no triangulation, but when the size, nature of the country, and state of the natives are considered the work reflects great credit upon those who did it.

Since the American occupation the United States Army has done practically all the mapping which has been accomplished in Mindanao. The work of this organization has been excellent. Besides making route maps of all the country traversed in the course of its expeditions, it has begun a progressive military map which shows the topography by contours, based on triangulation. This will, when completed, be by far the most accurate work done over so large an area by any organization in these Islands.

The United States Coast and Geodetic Survey is now engaged in surveying the coasts of the southern islands.

Much less has been accomplished in relation to the geology, but there is ample excuse for this lack of results. To use the expression of Dr. G. F. Becker, "such work in a country where the natives are not on the best of terms with you is more exciting than profitable."

Among our Spanish predecessors, Sainz de Baranda, Centeno, Montano, Espiña, and Abella have contributed to our knowledge of the geology of Mindanao. The work of the latter was confined almost entirely to the Misamis region, but it is the best of all the contributions from that part of the island.

The following appear among other Europeans who collected in Mindanao or studied its geology: Semper, Richthofen, Minard, and Renard. K. Martin worked on some fossils which came from Mindanao and Oebbeke described certain rocks collected on that island. Martin and Oebbeke have never been in the region.

Dana, Ashburner, and Nichols were Americans who visited Mindanao before the American occupation and who contributed to a knowledge of its geology and finally, Dr. Becker was in the Archipelago in 1898, just at the outbreak of hostilities with the natives.

Guillemard and Becker seem to have been the only investigators who touched at any part of the Sulu group. The former barely mentions Cagayan de Sulu, and the latter could only study the islands from the deck of the vessel, as the natives were at that time in a very warlike humor.

Dr. Becker[1] in his report gives a brief summary of the previous work in Mindanao and the following is a quotation:

"Concerning the great Island of Mindanao, only scattered observations are available. Sainz de Baranda[2] noted the occurrence of serpentine on the east coast of the island at Canmahat and in Misamis Province at Pigtao. Mr. Centeno states that at Pigholugan, near Cagayan, in the Province of Misamis, there are quartz veins in talcose schists. The auriferous districts of the Province of Surigao may, he points out, be regarded as a continuation of the Misamis district. The most notable deposits here are in the mountains of Canimon, Binuton, and Canmahat, a day's journey southward from the town of Surigao. The terrane is here composed of much altered talcose slate and serpentine.[3] Mr. Semper collected on the Maputi, which is an upper tributary of the Agusan River in Surigao. Here he found a uralitic gabbro and a chloritized, aphanitic, augite-plagioclase rock, containing a few plagioclase phenocrysts. The specimens have been described by Mr. Oebbeke.[4] They are probably facies of the melaphyres found by Mr. Montano. Mr. Ashburner examined a slate belt in the extreme northern portion of the island, about 8 miles to the southward of the town of Surigao, at the headwaters of the Cansuran River. It contains auriferous quartz stringers. Mr. Montano collected melaphyres at a number of points in eastern Mindanao. Such are the eastern shore of the Bay of Butuan, the eastern coast of the island between Bislig and Catel, and the divide between the waters which flow northward into Butuan Bay and those which flow southward into the Gulf of Davao. The river of this southern drainage basin Montano terms the Sahug. Other authorities give it different names. In its headwaters he found float consisting of melaphyre and quartz porphyries. Melaphyre he found again at Pujada Bay near Cape San Agustin. Quartz breccias also occur on the divide between Pujada and the Gulf of Davao. Serpentine accompanies the melaphyre to the south of Bislig.[5]

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[1] Report on the Geology of the Philippine Islands, *U. S. G. S. 21st An. Rep.* (1899–1900), Pt. 3, 507.

[2] He also mentions crystals of rutile from an island called Bigat, which is unknown to me. *Anal. d. Min.*, Madrid (1841), 2, 197–212.

[3] Memoria geológico-minera (1876), 49.

[4] *Neues Jahrb. f. Mineral.*, etc. (1881), Beil.-Band 1, 498.

"Mr. Minard visited the gold-bearing region of Misamis, the northwestern province of Mindanao. The sandstones and conglomerates of the Iponan Valley, dipping 12°, are said to be broken through at many points by diorite and serpentine. The pebbles of the conglomerates include diorites, augite-porphyry, serpentine, jasper, and marble.[6] Some years later Mr. Abella made a reconnaissance of this region, examining the gold deposits along the courses of several rivers, all of which empty into Macajalar Bay. They are the Iponan, the Cagayan, the Bigaan, and the Cutman. In this region he found two considerable areas of old slates. One of these touches the Iponan River 10 or 12 miles from the sea. The other is intersected by the Cutman and approaches the sea within 2 miles, near the town of Agusan, which lies at the mouth of the Cutman River. Alluvial deposits fringe the shore of the bay and follow the streams. Otherwise the country, as depicted by Mr. Abella, is covered with strata provisionally referred to the Miocene. The slates are described as metamorphic and in part steatitic. The pebbles of the Tertiary conglomerates consist of such slates, serpentinoid rocks, and many varieties of 'trachytic rocks.' I think that at the date of his memoir, 1879, Mr. Abella used this term for neo-volcanic rocks not basaltic in appearance. The description of the fossiliferous rocks overlying the slate leaves no doubt but that they are Tertiary or Recent, a fact which it is difficult to reconcile with Mr. Minard's statement that they are cut by serpentine and diorite. In the placer at the Bigtog, tributary to the Cagayan, Mr. Abella found slightly rounded, large pebbles of orthoclase.[7]

"A few miles northwest of Zamboanga (in southwestern Mindanao), at Caldera, Dana observed hornblendic and talcose schist in pebbles,[8] and on Malanipa, about 13 miles E. by S. from Zamboanga, the *Challenger* expedition collected serpentinized peridotite, studied by Mr. Renard."[9]

III. GENERAL GEOGRAPHIC DESCRIPTION AND ITINERARY.

The main body of the Philippine Archipelago is connected with Borneo by two parallel chains of islands, one consists of Busuanga, Linapacan, Palawan and Balabac, while the other extends southwest from the Zamboanga Peninsula, comprising Basilan, Sulu, Siasi, and Tawi-Tawi. The inference is that there has been entire land connection at some time in the past. This question will be referred to in a future chapter, at this place it is sufficient to state that there are some objections of a very reasonable nature to such a conclusion.

The Sulu Group and Mindanao together possess a rough likeness to a long-handled dipper, the Sulu Islands and Zamboanga Peninsula constituting the handle, the eastern part of Mindanao the bowl. Mindanao is marked by its great number of bays and gulfs, its two great rivers, its nine or ten lakes and its high mountains. One of the latter, Mount Apo, 2,928 meters, is supposed to be the highest peak in the Archipelago

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[5] Mission aux îles Phil. (1879–1881), 272–277.

[6] *Bull. Soc. géol.* France (1874), V, 2, 403–406.

[7] Mem. acerca de los criaderos auriferos . . . Misamis (1879), 4, 18, 32, 45.

[8] *U. S. Expl. Exp.* (1849), 10, 539.

[9] *Ibid.*

A glance at the map of Mindanao prepared by the Jesuits will reveal the presence of four main tectonic lines, three of which run approximately north and south, and the fourth east and west. The first is the line following the crest of the range which extends parallel to the long axis of the Zamboanga Peninsula; its direction is N. 20° E. The second seems most nearly to mark the eastward trend of this range; its direction is approximately N. 85° W. Along this line are to be found Mount Sugarloaf, just north of Dumankilis Bay, Mount Dapan, a short distance southwest of Lake Lanao, Mounts Kalatungan and Latukan east of the lake, and Mount Agtunganon east of the Agusan River.

The next line is that which follows the Apo Range. This is very pronounced from Apo southward, but is not especially marked to the north. On this line are to be found Mount Apo, 2,928 meters, and Mount Matutun, which is doubtless somewhat lower.

The fourth, which is not as straight as the others, extends along the backbone of the country east of the Agusan River; its general direction is about N. 8° W. No very important peaks exist along its extent.

The first of these four lines, which follows the backbone of the Zamboanga Peninsula, is the most marked in that it extends northward through the Island of Negros, coinciding exactly with the tectonic line of that island and cuts across the lower part of the prong of Masbate, again coinciding with the long axis of Sorsogon and the Catanduanes. The Agusan line, by curving a little to the west, would fit closely with the tectonic lines of Leyte, Masbate, and Tayabas. There is no question but that there is a definite and fairly uniform system of folding and fracturing throughout the Archipelago, the various islands representing the irregular crests of the anticlines while the intervening straits mark the synclines.

There are no very large rivers in the western part of Mindanao, although a fair-sized river follows along the central line of the Zamboanga Peninsula, and two short, swift streams also exist, one of them, the Agus, draining Lake Lanao and emptying into Iligan Bay after a run of about 30 kilometers, and the other, the Mataling River, drawing part of its water from Dapan Lake and part from the northern slopes of the Kulingtan Range. A different condition exists in other parts of Mindanao.

The *Rio Grande de Mindanao,* over 300 kilometers long, is the second largest river in the Philippine Archipelago. Its course is from north to south until within a short distance of Lake Liguasan where it turns sharply to the west, emptying into Illana Bay. This river is navigable for shallow-bottomed, stern-wheel steamers for a distance of over 200 kilometers. The valley of the Rio Grande presents a wonderful stretch of country.

The Agusan River, next in size, flows from south to north in a fairly uniform direction. It is probably at least 250 kilometers in length.

Mindanao in general is rather densely covered with jungle containing much fine forest. No large industries, unless it be agriculture, exist in the island, if one sawmill, erected by Americans not far from the town of Zamboanga is excepted. There are neither mines nor factories, the little that has been accomplished has, for the greater part been the result of the energy of a few Americans and Spaniards. For the most part this great and enormously fertile island is a silent, almost trackless jungle.

We can only conjecture what the mineral wealth of Mindanao really is, for few as yet have had the hardihood to attempt prospecting in this region.

IV. PEOPLE.

The distribution of the different tribes can be learned by reference to the map prepared by Dr. N. M. Saleeby [10] to accompany his researches into the life of these people. It is not my intention to discuss very fully the racial characteristics of the people inhabiting Mindanao, as Dr. Saleeby will do this fully and thoroughly. However, it will be necessary to make brief mention of the character of the inhabitants in this paper and to make this portion as accurate as possible I have not only drawn from personal observations, but more frequently from Dr. Saleeby's first work.[11] Other sources of information have also been used.

A line extending roughly from Iligan in a southeasterly direction to the Kidapwan Mountains and thence south to Sarangani Bay will divide the island into two great ethnological divisions. To the west of this line the Moros, a Mohammedan people, are dominant. To the east are various tribes which in all probability spring from Malay stock and who presumably came to Mindanao long before the Mohammedan invasion. The Sulu group to the south of Mindanao is inhabited almost entirely by Moros.

A considerable number of Visayans and a few Tagalogs, who have emigrated from the northern islands, are encountered along the coasts and at the mouths of some of the rivers.

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[10] Saleeby, N. M.: The History of Sulu, *Pub. Div. Eth., Bureau of Science*, Manila (1908), 5, II. The map of Mindanao will be published in Dr. Saleeby's work "The History of Magindanao" now in course of preparation.

[11] Saleeby, N. M.: Studies in Moro History, Law, and Religion, *Pub. Eth. Sur.*, Manila (1905), 4, I.

V. CLIMATE.

It is difficult to discuss the meteorologic conditions of Mindanao in a general way. The fairly regular and distinctly marked seasons which prevail in Luzon do not seem to obtain in Mindanao. The following table is taken from the monthly reports of the Philippine Weather Bureau:

Rainfall, in millimeters, at Mindanao and Sulu stations during 1905.

Month.	Zamboanga.	Isabela.	Jolo.	Davao.	Surigao.
January	8.7	13.2	38.1	79.0	105.3
February	2.6	1.5	0.0	121.4	101.1
March	0.0	0.0	22.4	206.2	81.9
April	37.3	9.6	0.0	88.4	130.6
May	143.5	102.4	305.0	417.8	176.9
June	25.3	54.0	19.6	192.8	0.0
July	214.6	140.2	209.9	341.4	167.3
August	84.1	112.4	38.9	328.3	112.0
September	62.6	145.3	229.6	160.6	216.8
October	148.2	320.9	420.4	127.8	112.8
November	107.7	112.3	59.4	66.5	380.4
December	57.7	91.2	69.6	------------	483.6
Total	892.3	1,103.0	1,412.9	2,129.7	2,068.7

A great difference is shown between the rainfall at Zamboanga, at Surigao and at Davao, and the results are very evident in the difference between the forests of these portions of the island. Zamboanga Peninsula is fairly well forested, if the plain which has been cultivated for a long time is excepted, but the forest of this region is not by any means as luxuriant as that of the Agusan and Davao Valleys. The densest forests in the Philippine Islands, with the possible exception of portions of Mindoro, are probably to be found in the latter districts.

I was not in the country for a sufficient length of time to render any statement I might make in regard to the healthfulness of various parts of Mindanao of value. The low country in the river valleys and the lake region to the south of the Cotabato is probably not as healthful as the highlands of the Lanao region. Mosquitoes abound in many parts of the former territory and great precautions must be taken against them. The Cotabato River has a particularly bad, but I think underserved, reputation in this respect. I had no fever nor any sickness whatever during the five months I was in Mindanao, but both native and American troops have suffered considerably from malaria.

A table of the temperatures for the various stations of the island follows:

Table showing mean maximum and mean minimum temperatures, in degrees centigrade, for Mindanao stations during 1907.

Month.	Surigao.		Jolo.		Isabela.		Zamboanga.		Davao.		Cotabato.		Dapitan.		Butuan.		Carago.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
January	29.6	21.8			30.9	21.5	30.3	21.8	32.2	22.5				23.1	28.4	21.3	30.6	21.8
February		22.4			31.3	21.9	30.3	22.3	31.7	22.3				22.6	28.6	21.7	29.5	21.9
March	29.6	21.6			31.6	22.2	30.9	22.8		22.6				23.6	29.4	21.9	29.7	21.7
April					31.4	22.0	30.6	23.0	32.7	23.0				23.6	31.0	22.2	30.5	22.0
May					31.6	22.3	30.6	23.3	33.0	23.0				23.6	33.0	23.8		
June	32.4	22.9			31.2	22.5	30.1	23.3	32.8	23.2				22.9	32.8	22.7	30.2	22.6
July	33.0	23.2			31.0	22.1	29.7	22.9	31.6	22.3	33.0	22.3		22.4		22.1	31.1	22.3
August					30.5	21.9	29.2	22.7	31.4	22.8	32.0	22.0		23.2		23.0	30.8	22.6
September			32.3	23.5	30.4	21.9	29.6	23.1	33.3	22.4	32.6	21.7		23.8	31.3	29.9		
October			31.8	22.3	30.2	22.4	30.3	22.9	33.0	22.4	33.6	22.2		24.1	30.3	22.5		
November			31.2	22.9	30.3	22.6	30.3	23.0	32.5	22.3	33.6	22.0		23.7	28.9	21.8		
December	28.3	22.1	30.9	23.2	30.6	22.6	29.7	23.0	30.9	22.3	33.2	22.1		23.3	27.9	22.2		

The region around Camp Keithley, owing to its altitude is much cooler than the low country and the climate is correspondingly invigorating. However, at certain times of the year, particularly in December and January these posts are said to be very disagreeable, as they are cold and raw like the New England coast of the United States in the spring time.

Typhoons are said not to occur in the latitude of Mindanao and the Sulu Islands. The evident reason for this is that the cyclonic storms, which have their origin in the Pacific are formed in a latitude much north of that of Mindanao and as they pass westward they are constantly curving to the north, partly owing to the original, clockwise movement of cyclones north of the equator and partly because of their approach to the continent of Asia. According to Father Algué, Director of the Philippine Weather Bureau, a few cyclones form in the Sulu Sea, but these attain no great importance either in frequency or in intensity.

Plate XXIX of Father Algué's "Cyclones of the Far East" [12] shows the mean trajectories of cyclones which pass over or near the Archipelago. It is very interesting in that it reveals how very generally Mindanao and the Sulu group escape these destructive storms. This fact is of the first importance in view of damage which such storms might inflict on crops, particularly on hemp which grows to heights varying from 10 to 18 feet, and because of the relative immunity from danger to vessels, such as interisland trading ships, Moro *vintas* and pearling boats.

VI. NARRATIVE OF THE EXPEDITION.

Zamboanga, the first point visited by me, is situated about 3 miles from the nearest foothills at the edge of a flat plain of considerable area at the foot of the long, narrow peninsula of the same name. (See map, Plate I.) To the east is a long stretch of salt-water marsh and in its rear is a scarcely less elevated tract which is taken up with paddy fields. If the Tumaga River had kept its initial direction, it would cut through the heart of the city, as it is, it curves to the east and enters the sea opposite Sakol Island. The substructure of this plain is coral, the superstructure, silt and coarse detrital material from the hills to the north.

Zamboanga is essentially a "gate city" and a study of the map will show its central, commanding position with reference to steamship routes. In fact this is the main feature controlling its location. It is not situated on a large river by which communication can be maintained with the interior and for this reason its position is not favorable as is that of Manila, which is on a plain on the coast and at the same time on the banks of a large stream which taps a great stretch of the interior. Cotabato, on the *Rio Grande de Mindanao,* is also favorably located and it will probably expand when the immense possibilities of the country to which it holds the key are understood.

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[12] Algué, José: The Cyclones of the Far East, Bureau of Public Printing, Manila, 1904.

The initial reconnaissance which I undertook was to Boalon, some 10 or 12 kilometers northeast of Zamboanga. Here the transportation by wagon was left and a trail taken which led up an abrupt hill a little beyond which point we entered the forest. Between Boalon and this hill I found some float limestone with fragments of *Orbitoides,* which probably are identical with the material Richthofen[13] encountered so many years before. This is practically all he contributed to the geology of this region, but this is not suprising when the attitude of the natives at that time is considered.

We continued in the forest for about three days, obtaining absolutely no view of the country farther than 50 yards from the trail, until we reached a log cabin about 30 miles north of Zamboanga on the Tumaga River.[14]

The country rock in this region is a much decomposed schist, with a considerable thickness of stiff, yellow, clay overburden. (Plate III.) Quartz pebbles and bowlders are plentiful in the clay; the pebbles come from quartz stringers in the schist. The large bowlders clearly indicate large veins, but we were not so fortunate as to encounter any of the latter. The clay contains a small amount of gold which the prospectors had recovered by sluicing. Few people were encountered in this forest. On our return after three days' stay we followed the river for perhaps 25 kilometers. At times we came upon box cañons (some of which we might have swum through), but usually we took the high trail which went along the steep side of the cliff, at times 30 meters above the water and rocks. The way was extremely difficult; the sharp river rocks, the sharp-edged schists and the leeches began to tell on our carriers, so that we finally took a trail which led out of the river and after a climb up the side of the gorge we regained the old path which we followed to a hemp plantation at the edge of the timber and by mid-day arrived in Zamboanga.

VICINITY OF SAN RAMON.

My next reconnaissance was in the vicinity of the San Ramon Farm, controlled by the Moro Province. This excursion was for the purpose of an examination of the mountains which rise abruptly back of the narrow coastal plain. The formation in this place is entirely volcanic, the rich, disintegrated débris spreading out upon the coastal plain and producing a very fertile soil. Some of the rock is highly pyritized and may carry more or less gold.

In the streams I saw bowlders of andesite which sometimes contained large fragments of schist, torn off and caught up in the molten rock as it poured out over the surface. This schist is identical with that found in the gorge of the Tumaga River.

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[13] Richthofen, F. von: Vorkommen der Nummulitenformation in den Philippinen, *Ztschr. d. deutsch. geol. Ges.* (1862), **14**, 357.

[14] A sketch map of the trail was made, but it shows little beyond the path.

I had observed terraces along the shore farther to the north in the neighborhood of Dapitan and therefore looked for some signs of elevation here. I did find one fairly well preserved terrace a few miles to the north of San Ramon, but the streams have cut through it in so many places that only an especially trained eye can see it. This terrace is perhaps 6 meters above the mean tide level. (Plate VII.) The mountains in the Zamboanga Peninsula were once covered with a mantle of limestone, but little of the latter remains, a few large bowlders in the streams being all that we could find.

This coastal strip on which San Ramon is located, disappears to the north at Patalun Point, but it widens regularly to the south and is everywhere taken up with coconut culture. The long stretch of sandy littoral from San Ramon to Zamboanga is especially adapted to the culture of the coconut palm.

This peninsula in regard to its population might be divided into the following zones:

1. The hill or forestal zone occupied by Subanuns, a wild and primitive people.
2. The intermediate or rice zone by Filipinos, mostly Visayans.
3. The coastal plain by Chinese and Americans.
4. The beach zone by the Moros (littoral zone).

COAL MINES AT SIBUGUEY.

Following the reconnaissances outlined above I went to Sibuguey Bay, an all-night run by Constabulary vessel to the northeast of Zamboanga. I was accompanied on this trip by Colonel W. C. Taylor, then in command of the Fifth Constabulary District. We anchored about a half mile offshore as we did not know the exact configuration of the reefs, this coast being but incompletely charted.

Our road to the coal measures at Sibuguey was first by boat up the Siay River, the banks of which for some distance from the mouth are lined with mangrove swamps, we taking a turn through an opening in the right bank and following an estuary until noon, when we landed and followed a trail over a low hill to the house of the *datu* of this region, Lukas, a Subanun. (See Plate VIII.)

We left this place early in the afternoon and after a very trying march through mud and over hills, we reached the site of the coal workings on the Sibuguey River. The old, abandoned tunnels of the coal mines are hidden by the underbrush. I could obtain but little idea of the condition of the seams, excepting that they are tilted and dip to the southeast. They can be worked with the mine mouth probably not over 100 meters from the Sibuguey River, which is large enough at this point, 21 kilometers from the mouth, to allow small launches and lighters to pass up and down to take on coal.

THE SULU ARCHIPELAGO.

The Sulu Archipelago is practically unknown from a geologic and physiographic point of view, so that the information gained in this expedition, although meager, is at least new.

Dr. Becker refers in four lines of his report to rocks on Marongas Island just across from the town of Jolo. Other than this there are no geological notes. Some eruptions of the year 1614 are described by the resident Jesuits but only in a crude way. It has been known for a long time from the reports of ship captains and travelers that the archipelago is largely volcanic.

This great group of islands extends for 335 kilometers southwest of Zamboanga. It is about 120 kilometers wide and contains hundreds of islands and rocky shoals. The most considerable of the islands are Basilan, Sulu, Siasi, and Tawi-Tawi and although Basilan is the largest, Sulu is of far greater commercial and historic interest.

The water is nowhere of great depth within the confines of this archipelago, but it is separated both from Borneo and Mindanao by deep straits. To reconstruct a large island out of this swarm of small ones which may or may not have formed a continuous bridge from Borneo to Zamboanga, and which would since have been disrupted and partly submerged, is not a great tax upon the imagination. The evidence we have points in this direction.

The Sulu group, like so many other oceanic islands, is either of volcanic or coral formation. I saw very little sedimentary material on any of the islands and where any such was exposed, it was usually at a point where erosion had removed the lava capping. I do not know of any marked volcanic activity in the Sulu Archipelago at the present time, although hot springs in old craters are reported on Cagayan Sulu. I have also been informed that there are hot springs and solfataras at Si'it Lake on Sulu. This lake occupies an old crater. I have visited neither of these places.

An eruption at a point near Jolo, not named, is reported to have occurred on January 4, 1641.[15] As there is some confusion of names in this report I do not attach much importance to the account. As far as I can learn, no accurate scientific notes were taken at the time.

The only remaining reference I find regarding the geography or geology of the Sulu Archipelago is a note by Becker:[16]

> "In the Jolo Archipelago, the charts indicate several well-developed atolls, such as Simonul Island (latitude 4° 52', longitude 119° 50'), as well as several in the Tapul group (latitude 5° 30'). The charts of this region also show innumerable coral reefs, which are bare at low tide and must therefore have been uplifted."

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[15] Baranera, Francisco X.: Compendio de geografía de las Islas Filipinas, Marianas, Jolo y Carolinas. 3r ed. Manila, 1892.

[16] Geology of the Philippine Islands, 562.

I myself have seen some coral islands near Sulu, in the Pangutaran group; some of these are atolls and others were formerly lagoons that have dried up because of the elevation of the whole mass.

While nearly all the elevations are extinct or dormant craters, there are no sharp, jagged profiles, but instead, most graceful curves. There are nearly fifty of these cones on the Island of Sulu, some still high and symmetrical, others irregular and worn down to mere stumps. (See Pl. IV.)

BUD DAJO.

We first visited the now historic crater of Bud Dajo,[17] the wooded cone of which rises from the plain back of Jolo. One afternoon of brisk riding on horseback is necessary to reach the point where the very steep climb begins at 300 meters' altitude; from here to the extinct crater is a further elevation of 580 meters. The climb is a short one, but it is the most strenuous I remember ever to have made.

Formerly there existed a community on this mountain having all the necessaries of life about them; a complete village with dwellings and a mosque; springs, gardens, and both shade and fruit trees, all within an extinct crater. The Moros added trenches and *cottas* to the natural walls of the village and long bamboos, in the hollows of which were concealed *lantakas* (brass cannon) were placed along them. (See Plate X.)

Bud Dajo is formed of scoriaceous basalt and lapilli, but has not been in eruption at least within the last three hundred years, or if it has, there is no record of the event. Large basaltic bowlders from this mountain are strewn over the slopes and the plain down to the very edge of the town of Jolo. An excellent view of a large part of the island can be had from the highest point on the walls of the crater. From this point smaller craters are visible and it is not impossible that renewed energy may at some future time be manifested at one or more of the many foci and a considerable destruction of lives and property be the result. The fact that these craters appear extinct is no argument against future activity.

FURTHER RECONNAISSANCE OF SULU.

On Monday, October 14, Lieutenant Caffery and I, with an escort of five men, began an expedition to Maymbung, on the opposite side of the island. The trail led past Asturias, the former residence of the Sultan of Sulu, but now the site of infantry barracks, and on over a low divide of about 300 meters' altitude, between Bud Agad and Bud Pula. The soil is of a rich red color, giving promise of unusual richness. Large fields of tapioca, which is the main agricultural product of the

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[17] *Bud* is the Sulu term for mountain. As it is generally used by the military authorities, it is retained in this description.

Sulu Islands, appear on either side of the trial and Moro dwellings, with several small haystacks near by could be seen from time to time. However, large tracts of fallow land exist along the route.

The soil everywhere is the same, for a blanket of basalt apparently lies over the whole island. At Maden Patung, about a mile and a half from the Sultan's house at Maymbung, are some outcrops of tuff, the only sedimentary formation I saw while on the Island of Sulu.

We reached Maymbung late in the afternoon and the next day returned to Jolo by the same route we had come by, our stay being cut short by the consideration that a geological reconnaissance conducted under guard in a very unsettled country does not warrant the expense and the additional detail of men. "Such work is really more exciting than profitable."

Several short excursions in the vicinity of Jolo were made for the purpose of finding water-bearing strata, but in this respect the result was disappointing. However, some splendid examples of old, worn-down craters were seen. Several low, circular and apparently flat-topped hills lie at a distance of 3 to 5 kilometers southwest of Asturias. They very much resemble overturned saucers. The tops of these hills usually show a more or less marked depression, a remnant of the old crater, and two of these were inhabited by several families, with substantial houses and well-kept gardens. These people live in such situations, not so much because the soil is particularly rich, because it would be hard to find soil more fertile than that on the lower volcanic slopes, but undoubtedly because of the protection afforded by the hills, the comparative difficulty of access and the excellent lookout over all approaching trails. There is usually some water either in the central depression or at the bases of these volcanic mesas.

OTHER ISLANDS OF THE SULU GROUP.

I returned to Zamboanga after this brief visit to Sulu and reshipped on a small Constabulary paymaster-boat for the more distant islands of the Sulu group. The first stopping place was at the Island of Bongao. Tawi-Tawi was not visited, such observations as were possible being made while sailing near to the coast. It is not a very rugged island, everywhere showing gentle curves.

Bongao is a small village and Constabulary station on the island of that name, separated by a narrow channel from the southwestern end of Tawi-Tawi. Coral reefs are found everywhere in these waters, so that great care in navigation is necessary. Mount Vigia, visible from the dock (see Plate XIV), is a mass of very resistant conglomerate, 370 meters high, and on a clear day the low coast of Borneo can be seen from this peak.

Some raised beaches exist in this vicinity and a number of fossils of recent age, clearly Pleistocene, were procured.

From Bongao we navigated through a labyrinth of islands along channels so narrow as to make it almost possible to lean over the side of the boat and touch the branches of the trees, and we finally anchored in the narrow straits between Siasi and Lapac Islands. We had but one or two hours of daylight at this point, but a short excursion inland gave us a fairly good idea of the geology and soil of Siasi. The soil, as in Sulu, is a rich, red volcanic material, and the underlying rock, wherever I saw it, was andesite or basalt, which is frequently difficult to classify exactly, because of the weathering to which it has been subjected. Very little timber is seen on this island, at least not on the side at which we touched, and there are no large streams. However, a dense growth of cogon grass prevents serious damage from erosion. If this grass were not present, loss would surely result owing to the lack of forest. On the other hand cogon, as in other parts of the islands, is a serious menace to agriculture. It is usually the custom of the natives annually to burn off this grass, but this method only affords temporary relief. A better way and one which is being practiced with success in many localities is to plow the cogon under for two or three seasons, when the roots rot and not only is the grass killed, but the soil is further enriched.

The next point visited was the large and geologically little known Island of Basilan. A portion of this island was occupied by the Spanish government, which had a small naval station at Isabela on the north coast. This has been abandoned since American occupation and the place has consequently fallen into neglect and decay.

But little geographical exploration has been done in Basilan. Mr. Dean C. Worcester and his party visited it about the year 1892, and the following is taken from his account.[18]

"Isabela, the capital of Basilan, is a small place of less than 1,000 souls. The only Spaniards there are the officials and the Jesuit priest. The town is on high ground, which slopes sharply down to the edge of the channel separating Basilan from the little island called Malamaui. This channel, although extremely narrow, is very deep, and large vessels can come close inshore. Tremendous currents rush through it with the ebb and flow of the tides.

"Isabela is a supply station for gunboats, the coal yard and magazines being located in Malamaui, just across from the town. To defend the important stores which they contain there is only a ridiculous old limestone fort on a neighboring hill, armed with two or three antiquated smoothbore cannon, and garrisoned by a few marines.

"The Moros of Basilan, locally called *Yacans*, have always borne a bad reputation, but at the time of our visit they were held in check by a remarkable man known as *Datu* (Chief) Pedro."

A picture of the fort mentioned above is shown on Plate XV.

Only two short trips were made into the country back of Isabela; the same basaltic flows and rich red soils exist here as in Sulu and Siasi. Vulcanism does not appear to be as recent in Basilan as in Sulu. At no place did I find that the streams had cut through the lava capping and exposed the sediments which I feel sure lie beneath.

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[18] Worcester, Dean C.: The Philippine Islands and their People. Macmillan, (1901), 144.

LAKE LANAO AND VICINITY.

All of the work in the region of Zamboanga and the Sulu Archipelago which it was at all feasible to undertake at this time having been completed, we left Zamboanga, November 6, for Overton. As our vessel kept close to the coast, I was able to make some notes which throw considerable light on the geologic changes now going on. The west coast of Mindanao has very certainly risen in comparatively recent times. Near Point Blanca on the northwestern part of the coast I saw a fine example of a raised delta, the elevation amounting to at least 10 meters. The characteristic structure of the delta was clearly revealed by the extensive marine erosion which had taken place. There were also many fine terraces shown along this coast and their existence supports the other evidence.

The weather compelled us to run into a little cove near the point just off Dapitan. Of all the many inlets along the coasts of these islands I believe this to be one of the prettiest and most secure. No sign of an entrance can be seen at less than a kilometer away and certainly this point would be too obscure to pick up at night. We went through a channel not over 45 meters wide between walls which in the darkness I took to be limestone, and emerged into a splendid basin with water as clear and placid as a mountain lake and with high walls on nearly all sides.

By noon of the next day we anchored off the little stone fort at the entrance of Panguil Bay, which is in the extreme southwest corner of the much larger Bay of Iligan. The most conspicuous object at this place is Mount Malindang, an extinct volcano close to 2,700 meters in elevation lying to the west. Material from the slopes of this mountain is basaltic as I discovered by going up Panguil Bay in a *banca* in company with Lieutenant Lattamore, Philippines Constabulary, and a detachment of soldiers, landing at several points to enable me to go far enough inland to examine the rocks, as there are no outcrops on the coast.

Mount Malindang is an old crater the rim of which is broken down on the side toward Misamis. It is for the most part covered with a luxuriant mantle of timber forest; the soil on its slopes is of a rich red and is undoubtedly very fertile.

A number of Visayan colonies exist on the west side of Panguil Bay, but all the country to the east is Moro.

We left this point on the morning of November 11 and reached Camp Overton at a little after noon. Mr. Ickis was to join me at this point, but as he was detained by quarantine, Lieutenant Caffery and I went forward over the military road to Camp Keithley (745 meters) where the climate is much cooler than in the coast towns.

There is very little coastal plain in the region of Camp Overton, the hills rising so abruptly that the road has to wind back and forth in order to make the ascent. The first part passes through raised coral reefs, in which the species are for the most part identical with those growing in the sea below, but within about 300 meters the road cuts through basalt, and continues in this formation until Malabang on the southwest coast of this portion of the island is reached. Maria Christina Falls are situated but a short distance off the main road, a few kilometers out from Overton. Here the swift waters of the Agus River, which drains Lake Lanao, fall over a cliff 58 meters high and continue to the sea through a narrow gorge.

It has been estimated that sufficient power can be developed by these falls by means of turbines to run electric freight and passenger trains from Camp Overton to Camp Keithley and then around the lake and down to Malabang. Furthermore, the power from this and the Mataling Falls together should also be able to furnish electric light for a dozen towns and camps along this route.

The rock in the upper portion of the section at the waterfall is a hard, rather structureless basalt; below this comes a more or less loose volcanic conglomerate, or better, agglomerate, the geologic structure giving the most favorable conditions for fall formation. Maria Christina has about the same height and volume of water as the better known Majayjay Falls of Luzon.

The road, very soon after the fork to the waterfall, leaves the rather heavy timber. From here on it ascends a long, gradually sloping, quite open and rolling plain, resembling the western prairie of the United States.

The Agus flows in a broad valley with gently sloping sides at Numungan and while at this point it has a fairly rapid current, it gives no intimation whatever of the terrible plunge a few miles farther on. A party of engineers is stationed at Pantar some distance beyond this point to look after the roads and bridges, and we spent two days here to examine the cuts along the road and river bank. Basalt is still the country rock here, but it has on top an extraordinarily thick mantle of weathered material full of basalt bowlders, and both in constitution and topography this simulates glacial morainal material.

From Pantar the road runs fairly straight for seven to nine kilometers across open rolling country to the "Keithley escarpment." Beyond this escarpment lies Lake Lanao. The road continues almost due south to the foot of this great wall, then turns practically due east and, keeping nearly parallel with it, climbs gradually to the top. From here it runs down a long, easy grade to the margin of the lake.

This escarpment is very striking, and is made up from top to bottom, as far as can be seen from its cuts in the road, of loose material, unsorted and with apparently no definite structure, forming a wall 155 meters high. A simple explanation of this phenomenon is not easy to find.

To the left, when facing toward Camp Keithley from the top of the embankment, rises the dark, heavily wooded mass of "Sacred Mountain" some 300 meters higher. In the middle distance stands a prominent, grass-covered bump known as "Signal Hill" and beyond lies the lake and still farther back the dark, volcanic range of the Butig Mountains on the southeast. To the southwest the striking peaks known locally as "Ganasi" appear.

Usually, when the visitor first sees Lake Lanao, if he has any curiosity at all, he seeks the most natural explanation in a volcanic region, namely, that it is a crater lake. There may be some resemblance to a crater rim on the south shore near Camp Vicars, but in other places there is no trace of it. I first was favorably inclined to the belief that it was a valley dammed by glacial wash and I found no trouble in likening the Keithley Escarpment to a terminal moraine. I was forced to abandon this hypothesis for reasons which will be stated in a paper on the geology of this region which is to follow. My provisional conclusion with regard to Lake Lanao is that it occupies an old basin, partly tectonic, partly caused by erosion, between the mountains; this basin has been dammed by lava flows and other volcanic materials from the mountains adjacent to it. Subsequent weathering has given the aspect of a pseudo-glacial till to the material forming this obstruction. The explosion-crater theory has occurred to me and some attention will be paid to it in this connection in the later geologic discussion.

Camp Keithley is situated partly on the brow of the escarpment of the same name and partly on the slope to the lake. The small village of Marahui lies on the lake shore on the west bank of the Agus. Here is the residence of the district governor and here too, the tribal court is held. This village also has a native market, so that Marahui is the best place in the whole lake region to see the Moro people.

Mr. Ickis joined the party in Marahui and we crossed Lake Lanao in a *vinta* with a large sail and awning made of some species of palm. It was almost nightfall when we ran into a small cove and landed, and in the darkness we began the ascent of 155 meters up the high bluff on which Camp Vicars is situated. This distance is between 4 and 5 kilometers. Three days later we set out for the Taraca River on the east side of the lake with an escort of twenty scouts, sixteen cargadores, and several guides. The country around Vicars is open and rolling and very similar to that south of Lake Lanao. Very little of the land is under cultivation.

On the second day we finally descended from the high bluff we had been following and crossed an estuary, thus saving many miles of circuitous travel. The low flats which border this side of the lake extend back for several miles. The trail on the other side of this estuary lies through paddies and swampy areas. Every morning during our march was clear and bright, but the afternoons without an exception were rainy.

The region through which we passed contains numerous Moro forts or walled towns termed "*cottas*" peculiar to the Lanao Lake district and to Sulu. The walls are several feet in thickness, made of earth, and protected by a dense hedge of bamboo growing at the top. A moat nearly always surrounds the *cotta* and a drawbridge of bamboo is provided. Bamboos, into the closed joints of which have been placed long, slender-barreled brass cannon, known as *lantakas*, are thrust through holes in the walls. The *lantakas* are imported from Singapore. We passed fifty or more of these *cottas* in our trip around this part of the lake. Some of them shelter only one or two houses, whereas others contain a score or more dwellings, mosques and other edifices, in fact an entire village. Each *datu* or sultan lives in his *cotta* with his family and retainers close about him, and there is constant petty warfare among the various chiefs.

On the fourth day we reached the Taraca River and stopped at the house of a friendly *datu*. His *cotta* was, perhaps, the most elaborate we had seen; an elevation is shown by fig. 1.

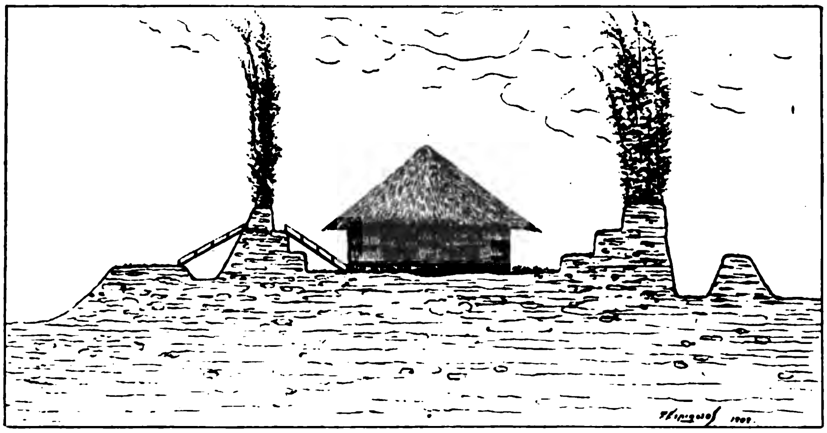

FIG. 1.

It was impracticable to ascend the Taraca River as far as the foothills to look for copper ore which had been reported from that point, because of the high water, the absence of trails along the bank, and the nature of the inhabitants. We did ascend for a distance of about 2 kilometers, but became almost hopelessly entangled in the ruins of old *cottas*, some recently destroyed by the Constabulary, others fallen into decay.

This condition caused us to continue our march to Camp Keithley and from here we again crossed the lake to Camp Vicars, from which point we set out for Malabang. The first portions of the road lie across an open, almost treeless country which affords a splendid view of the Buldung Range which runs in a long, high, serrated line eastward from Malabang, Some six or eight extinct craters of different heights, arranged so as to resemble steps, are visible in this range.

The road next enters heavy timber and at about one half the distance to Malabang, crosses the steel bridge over the Mataling River. The falls of Mataling are not so high as those of the Agus, but are scarcely less picturesque. The country rock is a basalt of more compact grain than at the other waterfall. The road runs into a very loose, black soil of sand and volcanic ash at a short distance beyond the bridge and continues in this formation to Malabang. This deposit of ash, at some distant date, issued from the now extinct Buldung craters. The most notable feature at Malabang is the line of cold springs issuing from the volcanic ash formation.

We next proceeded by trail from Malabang to Parang. Apparently all the country rock at Parang consists of basalt with well-developed columnar structure about 500 meters above the pumping station at the military post. Just south of the town the basalt sheet suddenly ends and sedimentaries, including coal measures, appear. Carbonaceous shales and certain fossiliferous beds indicative of coal deposits are here found, although no coal has as yet been opened up.

THE COTABATO REGION.

The country from Parang to Cotabato is rolling and but scantily timbered. The country rock consists of shales and soft sandstones dipping southward, that is, toward Cotabato. There are several small lakes in this region which are noteworthy, because of the great profusion of large, pink lotus and the abundance of ducks.

The difference between the topography in this region and that around Malabang is due to the absence of the lava capping which becomes thin just to the south of Parang. Whereas the streams in the lava country have a cross section like the following figure (fig. 2), those in the country to the southward beyond this sheet have more flaring sides to their valleys as is shown in fig. 3.

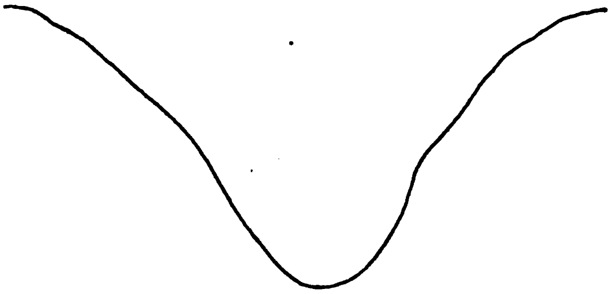

FIG. 2.

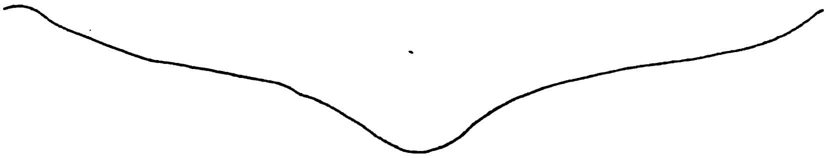

FIG. 3.

FROM COTABATO TO DAVAO.

The town of Cotabato is situated on the south bank of the north branch of the *Rio Grande de Mindanao.* It consists of a collection of low, white, Spanish houses fairly close together, with the usual native huts straggling about in the environs. Just south of and on the edge of the town is a limestone hill about 150 meters high from which a magnificent panorama (Plates XVI and XVII) can be obtained of the surrounding country. This hill is an outpost of a greater mass which is to be found to the south and which formerly was undoubtedly still more extensive; it is very remarkable in that it stands out in the middle of the great delta, which forms all the river plain from the mouth of the river back and even beyond Fort Pikit.

The most notable feature of the topography of this plain, beside the hill just mentioned, is the old terrace lines which swing along, but not always parallel to, either side of the river. These terraces are undoubtedly of marine origin, for close to Cotabato they are seen to be raised coral-reef shelves with the characteristic steep seaward slope of such formations. The evidence seems quite sufficient, to me at least, to suppose that the sea once swept far up this intermontane region which is now so filled with sediment. Indeed, I am convinced that it one time extended through to the Gulf of Davao, for in the stretch between the Pulangui River and Davao there are very recent sediments and volcanics which have closed up the passage.

Cotabato hill is composed of a cavernous limestone with a fair sprinkling of fossils, corals, gasteropods, lamellibranchs, etc., all of comparatively recent age, presumably Miocene, although no specific determinations have as yet been made.

Plate XVIII shows the interior of a native salt-making establishment at the lower end of the delta. Sea water is sprayed over glowing embers, the salt is precipitated and afterwards washed off and run through the large filter shown in the background of the picture. This filter contains wood ashes and earth. At the Moro foundry near Cotabato, bolos, krises, and many metal boxes of brass and silver are fashioned.

After some delay, we set out for *Datu* Piang's place at Cuderangan, some 50 kilometers above Cotabato. Here we learned from Lieutenant Younglof, Philippine Scouts, of oil seeping from the river bank about half way between Reina Regente and Fort Pikit and also near Pikit of a blue, plastic, oily clay which burns to a white color and is quite refractory. The Moros are said to come great distances to obtain this material.

Reina Regente is on a hill of limestone similar to that of Cotabato. It is a monadnock. The underlying foundation is sandstone which will doubtless be found to be a good water carrier; it is very probable that good conditions for artesian wells can be obtained at almost any point of the valley.

Fort Pikit, which dates from the Spanish régime, like Reina Regente, surmounts a limestone monadnock, but the latter is much higher than the one on which the former fort is situated. This is the farthest port on the Rio Grande.

From Fort Pikit we ascended to the end of navigation in the light-draft, stern-wheel steamboat which is used on the river. This point is some 50 kilometers beyond the fort, at the junction of the Kabacan with the Pulangui Rivers, the total ascent by steamboat being almost 200 kilometers.

The first three days of our march were through mud; we were continually forced to wade rivers, because we were following in the bed of the main stream, walking along the banks being out of the question, the first stop being at the junction of the Malabul and the Kabacan Rivers. We continued along the Malabul in a winding course, but making only 12 kilometers in a straight line in one day. A coarse, gritty sandstone and in places a typical conglomerate appear occasionally along the banks.

On the third day after we left Pikit, and six days' march from Davao, at an elevation of 365 meters, we reached the house of *Datu* Inkal, a Manobo chief. The geology in this region is not very prominent. The trail generally leads through dense underbrush. All the streams are filled with large bowlders of extrusive rock, evidently from the Matutan Range just ahead. The latter is represented on the Jesuit map as a long, continuous and rather formidable *Cordillera*, but it is nothing of the kind and, except for Mounts Apo and Matutan, it is merely a broken line of hills and quite low in several points.

The journey for the next few days can best be given by extracts from the diary.

December 16, 1907: Left *Datu* Inkal's at 7 a. m. Continued through jungle and over rolling country to an elevation of 580 meters where the trail goes through the pass. Halted and made camp beside a small stream. Rainy weather and leeches made traveling very disagreeable. The feet of the cargadores were bleeding freely, but they did not seem to mind it.

December 17, 1907: Broke camp at 7 a. m. Cloudy, elevation by barometer 472 meters. Crossed the Dalapnay River this morning. All the rocks for miles around this point appear to be similar, either fine-grained felsites, basalts and andesites or feldspar prophyries. Very little can be said geologically about this country at this time, as so little of it can really be seen. It apparently is extremely recent. Halted at noon at the Dalapnay River at a Manobo house and spent the afternoon of the 17th drying out our effects. Elevation at this point 412 meters.

December 18, 1907: All of this day we are going downhill through dry woods, for the most part consisting of small trees and little or no underbrush. Occasional basalt and andesitic bowlders are seen. The difference between this side (eastern) and the western side of the range is almost entirely due to the fact that the prevailing winds, moisture-laden from the Sulu Sea, give up their moisture on the western side of the mountains and the winds blowing off the Pacific lose much of theirs on the seaside of the mountains east of Davao. The appearance of these eastern-slope forests is not greatly unlike that of those in the Temperate Zone.

We halted for the night at 75 meters' elevation at Sinauilan Creek, where soft, brownish-gray sandstone and conglomerate is exposed.

December 19, 1907: Left camp at 6 a. m. Not much change either in topography or geology is apparent. Arrived at Digos, a small barrio on the coast of Davao Gulf, about 12 m., after a long walk over ground gently sloping to the beach. Here we spent the rest of the day and the night.

December 20, 1907: We sent our cargadores and guard on to Davao by trail while we took the launch *Bolinao* which stopped off this point at noon. We arrived at Davao about 7 p. m. after stopping at two or three plantations on the way and went ashore the morning of the 21st.

At Digos we obtained our first clear-cut view of Apo. The mountain stood out clearly and boldly, a sharp cone set to the south and back of an older truncated mass which had evidently blown off its head in some primordial paroxysm. On the southeastern side is a huge crevasse, from which puffs of a bluish-white vapor issue. Below 2,100 meters there is a dense jungle, a mass of green, but above this line the surface is all barren rock and apparently treeless, although when we ascended the mountain we found small bushes of blueberries.

The present high peak known as Apo did not pour the great mass of lava and rock over this entire region. The explosion crater was about 8 kilometers to the northeast. Fig. 4 shows a profile sketch of this mountain.[19]

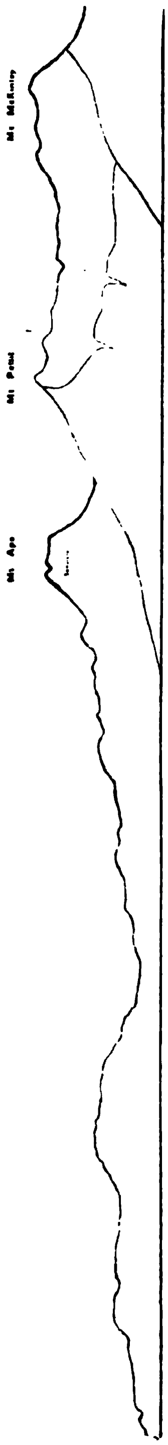

FIG. 4.

A walk back over the plain behind Davao is interesting. About 300 meters behind the town, or about 2 kilometers from the beach, unmistakable signs of old beach lines are found, marked by one distinct terrace at least 15 to 23 meters above the flat on which the town is located. All this territory is made up of alluvial wash from the hills. The bowlders are largely andesitic.

Lieutenant Caffery left the party at Davao to return to Zamboanga. Without his assistance the reconnaissance, up to the point where Davao was reached, would have been impossible.

Daron, on the west side of the Gulf of Davao, was the starting point for the ascent of Mount Apo, the party consisting of Mr. Ickis, Mr. Goodman, who had just arrived from Manila, and Messrs. Carrigan and

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[19] A good picture of Mount Apo will be found in the article on Volcanoes and Seismic Centers, in the Census of the Philippine Islands. (1903), 1, 201.

McCall, the last named having the kindness to furnish a launch to take us from Davao to Daron, and our thanks are extended to him for the courtesy.

We began the ascent of the first long, gradual slope toward Mount Apo on December 29. The trail first passes through hemp fields on the coastal plain and afterward it ascends gradually through a long, grassy slope which is strewn with occasional bowlders.

The first stopping place was at the house of Tankalin, the chief of the Bagobos. In appearance he and his people are very much like the Manobos. A short description of these people and one of their peculiar ceremonies has been given by me in a previous number of this JOURNAL.[20]

The remaining details of the ascent can best be given by extracts from the diary.

December 30: We are delayed because of lack of cargadores, the rear of our party not leaving until 10.30 a. m. We paused at 2.30 p. m. in the river bottom. Here some representative samples were collected from the bowlders in the agglomerate. These are largely angular and andesitic. The stream at this point is engorged in a steep-sided cañon, 300 meters deep. There are neither signs of ashes nor of lava in this cañon, although a great section is exposed. Everything points to there having been at some time a violent explosion, probably Krakatoan in magnitude. We pushed on to Pandaya, arriving 5.30 p. m. in a pouring rain and found one small, miserable hut.

The elevation of this place is 870 meters and in the early morning the temperature was 20°.5 C. During the night over half our carriers ran away, so we were left in a fairly precarious condition.

December 31: Messrs. Goodman and Ickis went ahead with part of the baggage; the remainder of the party remained to procure carriers, of whom we finally secured three, and to examine the rocks in the vicinity more carefully. There were five heavy packs, the lightest weighing 35 pounds. As Goodman and Ickis were also heavily loaded, all were compelled to assume the rôle of carriers.

The first, almost perpendicular rise of 180 meters was reached in a very short time, but the work was very trying to those who were unused to this kind of labor. The trail finally led along on a high ridge 300 meters above the water until nightfall.

January 1, 1908: About 10 a. m. some Bagobos came back on the trail as carriers, and soon after the camp of the advance party was reached. This place had been established by Major E. A. Mearns, Medical Corps, United States Army, who had been in this region collecting botanical and zoölogical material. The elevation as determined by the boiling-point method is 1,854 meters; the barometer reading giving 1,662 meters. This camp is situated on a little shoulder of the ridge in a fair growth of timber and close by is a small stream of cold water, containing both iron and sulphur salts in solution. The summit of the mountain can be seen from here through an opening in the trees and the fumes issuing from the huge crevasse on the eastern side are also plainly distinguishable. (See Plate XIX.)

January 2, 1908: The trail first leads upward through the heavy timber in the mossy forest belt, and then drops into a small creek bed which it follows up to 2,250 meters; here it passes beyond the timber line and through a growth of small blueberry bushes and stunted shrubs finally reaching exceedingly rough

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[20] *This Journal, Sec. A.* (1908), **3**, 188.

> ground; however, there are neither ashes nor lava. The pathway follows the south side of a huge crevasse visible from far below, and after following this for about 300 meters crosses to the north side and continues along it and around its head to a knife-edged ridge leading to the summit. This crevasse in some places is probably 20 meters deep and 250 wide, it has eight or ten vents from which vapors containing sulphur dioxide issue. A cone of fairly pure sulphur surrounds each vent; in individual cases these deposits may reach dimensions of several thousand kilos; possibly there may be 400 metric tons of this material altogether. It probably could not be handled conveniently.
>
> A clay tablet with the inscription—
>
> *La única Expedición á Volcan Apó*
> *1880*
> *Montano y Rajal*
>
> exists at about 2,350 meters' altitude.
>
> Our party reached the summit at a little after noon. So far as is now known, this is the highest mountain peak in the Philippine Archipelago. The altitude was determined by two trials with the boiling-point method, which gave respectively 2,956 and 2,902 meters. The barometric reading at the first trial showed 2,811 meters, which number is, of course, considerably in error. The old Spanish Coast and Geodetic chart of this region gives 3,143 meters, but work now being carried on by the Coast and Geodetic Survey of the United States shows that the Spanish work in these waters is in error.
>
> The records of several parties are found on the summit, the earliest encountered being that of Schadenberg and Koch, 1882. None of the Montano expedition of 1880 was visible and possibly the tablet at about 2,600 meters' altitude has been carelessly or maliciously removed from the top where it was originally placed.
>
> The highest point of the mountain, as determined by measurement, is reached by crossing a low sag to the next pinnacle, and here is placed a cairn containing a brass tube with a screw top marked "S. C." Inside is a neat scroll of the Sierra Club of California, duly stamped with its seal and signed by its president, John Miner. This scroll was deposited in the month of October of 1904, by Dr. E. B. Copeland, formerly of the Bureau of Science. Our party was the first to sign on the register.

Sights, with the transit, were taken at all prominent points of the topography and boiling-point determinations were also made, although the work was much hampered by fog. The weather cleared in the late afternoon and we were able to observe the panorama from the summit.

The Gulf of Davao was plainly visible with its island and coves, encircled by dark green wooded mountains and long volcanic slopes. The Rio Grande cuts across the foreground as a silver streak, extending far in the midst of many folds of green which continue without break to the skyline to the westward. The vast extent of the jungle in this island is very strongly impressed upon the observer. Mount Matutan is visible some 62 kilometers away, appearing as an isolated cone. It was sighted with a level, and appears to be but little lower, even at that distance, than the point on which we stood. If the curvature of the earth is taken into consideration, it is quite possible that Matutan will be found to be appreciably higher than Apo. No record, so far as I know, of an ascent of the former exists.

Mount Apo shows a circular depression suggestive of a crater at the top and, although the rock is igneous and gases issue from a great fissure in the side of the mountain, I would not, in the strictest sense, term it a volcano for the following reasons:

1. There are neither ashes nor signs of lava outpourings; the rock on this part of the mountain is rather more holocrystalline than effusives usually are.
2. The "crater," as it apparently shows no signs of the products of vulcanism about it, might be explained as a water erosion cirque; this question will be discussed more at length in the paper on the geology of Mindanao.
3. The structure of the mountain is schistose due to pressure and shows clearly that this is a structural peak. Plate XX shows this schistosity and its anticlinal course.

The morning temperature at the summit was 8° C. A small lake exists on a shoulder of the mountain, apparently about 500 meters below the summit; it was not visited. The return to Davao occupied two days. Here I left the expedition to return to Manila, and Messrs. Goodman and Ickis continued the reconnaissance from Davao to Surigao by way of the Agusan River.

ILLUSTRATIONS.

PLATE I. Map of Mindanao.
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IV. Sandstone slightly schistose in the Tumaga River, Zamboanga.
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VIII. *Datu* Lukas seated before his house.
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XV. Old Spanish fort at Isabela.
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XVII. Panorama of the lower part of the valley of the Rio Grande.
XVIII. A native salt-making establishment on the lower Rio Grande.
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XXI. Showing cencentric weathering in igneous rock.
XXII. Map of route from Cotabato Valley to Davao Gulf.
XXIII. Map of route from Davao Gulf to Mount Apo.
FIG. 1. (In the text.) Elevation of a *cotta*.
2. (In the text.) Valley with steep sides.
3. (In the text.) Valley with flaring sides.
4. (In the text.) Profile of Mount Apo.

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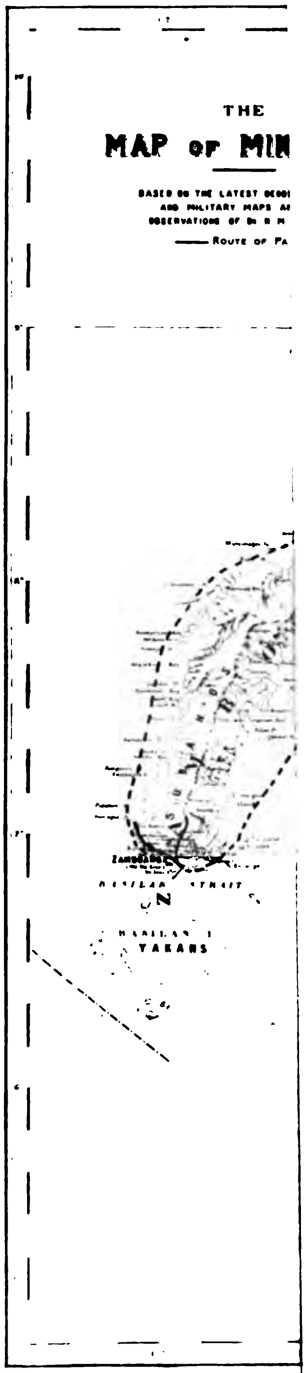
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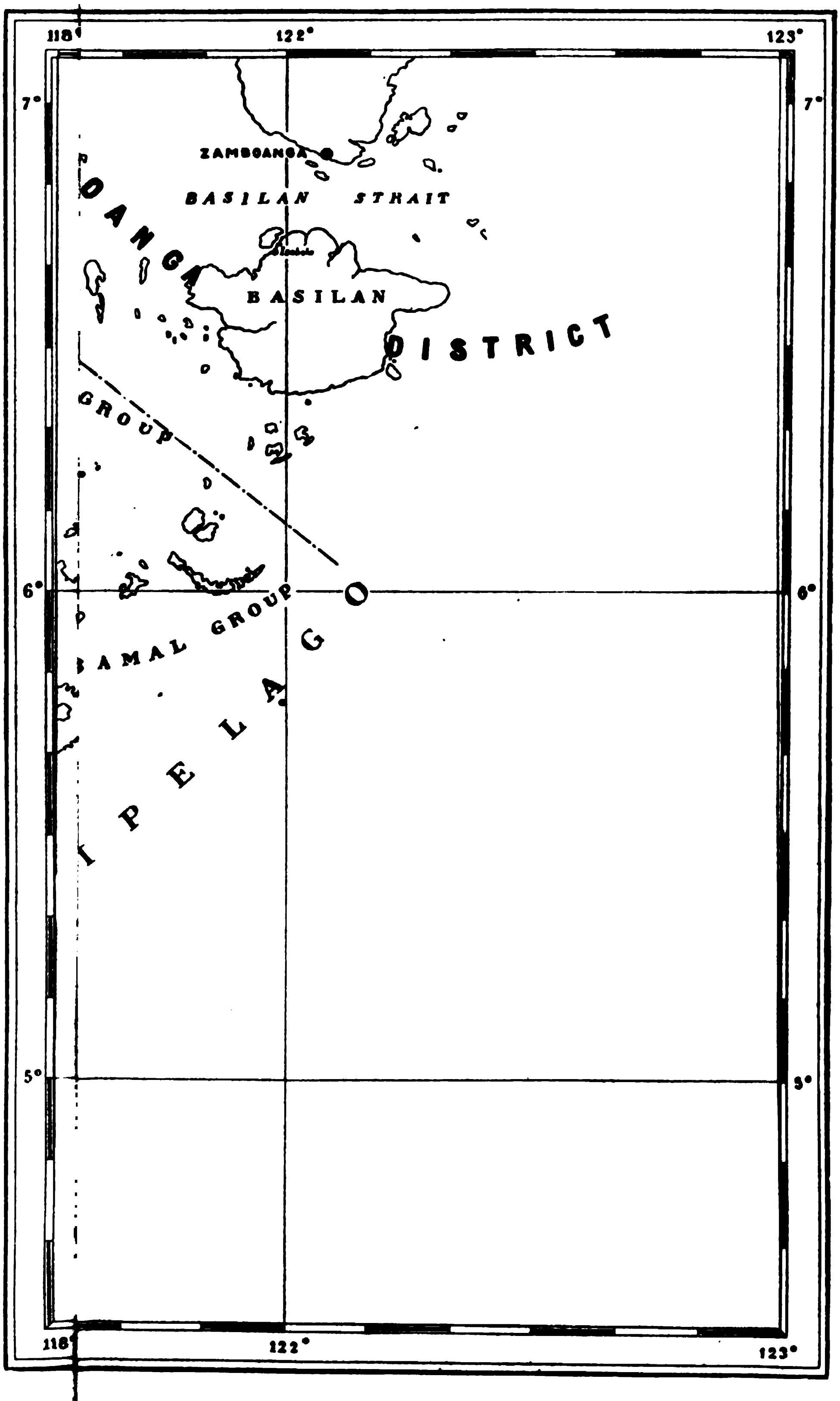
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PLATE III.

PLATE IV.

PLATE V.

PLATE VI.

PLATE VII.

PLATE VIII.

PLATE IX.

PLATE X.

PLATE XI.

PLATE XII.

PLATE XIII.

PLATE XIV.

PLATE XV.

PLATE XVI.

PLATE XVIII.

PLATE XIX.

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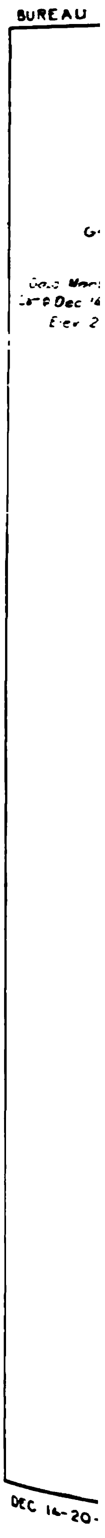
PLATE XX.

PLATE XXI.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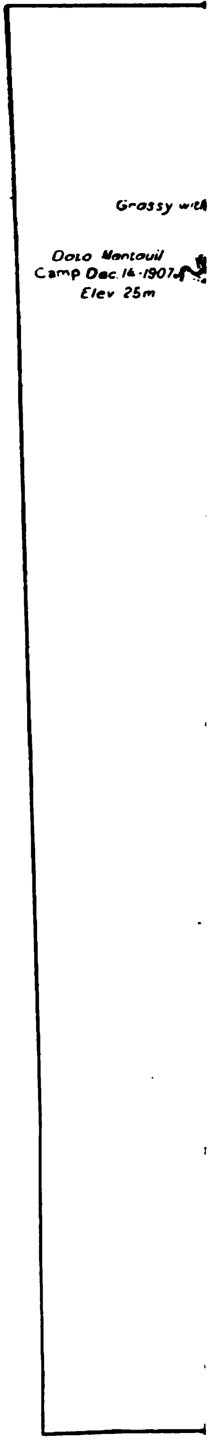

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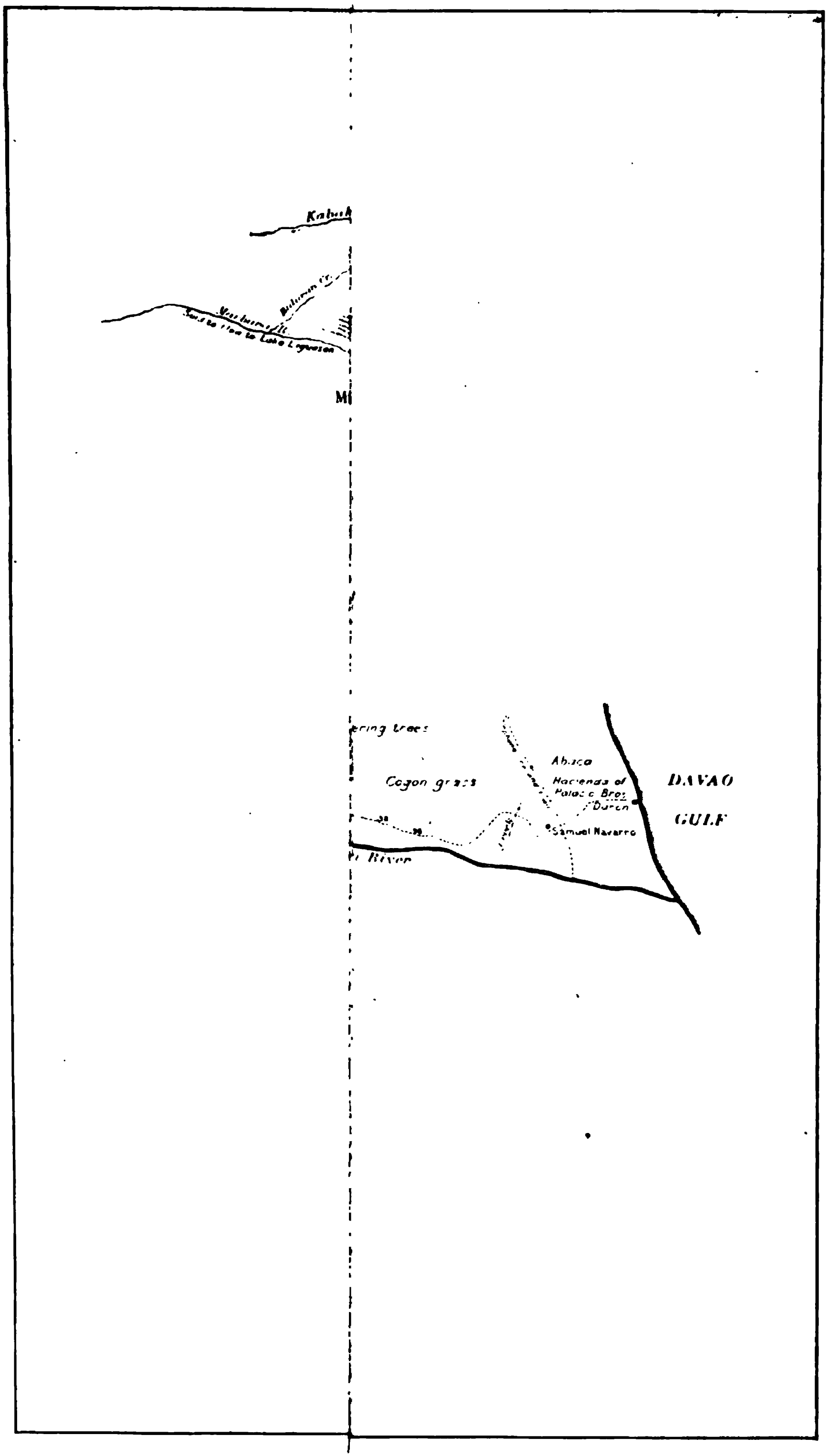

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